NOAA's New IOOS Program

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Abstract- **Having information about our environment is key to sustaining Earth, our way of life, and future generations. The Integrated Ocean Observing System (IOOS) is a nationally important infrastructure that will enable many different users to characterize, understand, predict and monitor changes in coastal and ocean environments and ecosystems. This infrastructure is critical to understanding, responding and adapting to the effects of severe weather, global-to-regional climate variability, and natural hazards. NOAA owns and operates much of the coastal and ocean observing and data distribution infrastructure. NOAA is the only federal agency that has responsibility for some aspect of all seven IOOS goals through our many mandates and programs; IOOS objectives are inherent to our mission. In December 2006, NOAA decided to standup an IOOS Program Office that will provide a central focal point for IOOS activities within NOAA. In the near-term NOAA will concentrate on developing a data integration framework. A fully operational data integration framework will take significant time to develop. However, we have set a 12 month goal of standing up the framework necessary to integrate five core IOOS variables, from multiple NOAA observing sources, for rapid and routine operational access and use by NOAA product developers and other end users. Between months 12 and 18, we expect to ingest these integrated variables into four specific NOAA data products. We will then systematically test and evaluate product enhancements, and verify, validate, and benchmark new performance specifications for operational use.**

Integrated regional coastal ocean observing system data, and effective regional management structures, are critical components of a fully realized U.S. IOOS program. NOAA intends to continue supporting the development and integration of these regional components. Regional partners are both producers and consumers of data and; therefore, will continue to have a role in the development of NOAA's IOOS data integration framework. The new office will serve as a focal point for the regions on U.S. IOOS efforts.

The paper will discuss how NOAA is approaching the data integration framework within the context of NOAA and our United States Federal and Non-Federal partners. Further, we will discuss the context of integrating data and the necessary standards definition that must be done not only within the United States but in a larger global context.

Conceptually, anyone interested in ocean observing or using ocean observations is a part of IOOS. Structurally, members include Federal agencies, state agencies, academic institutions, regional associations, trade associations, professional societies, business interests, public interest groups, and interested families and individuals. The IOOS model is assembling observations from diverse sponsors, thereby insuring innovation from independent perspectives, and yet establishing a foundation for all the diverse components to share data. The power of IOOS is synergy. Integrated data provides a board and synoptic view of our coastal, Great Lakes and ocean environments. By working together to integrate data we increase our knowledge of complex environmental phenomena which enables us to make better and smarter and coastal and ocean related management decisions.

I. INTRODUCTION

Having information about our environment is key to sustaining our planet, our way of life, and future generations. In 1990, 23 percent (or 1.2 billion people) of the world's population lived both within a 100 kilometer distance and 100 meter elevation of the coast, at densities about three times higher than the global average [1]. By 2010, 20 out of 30 megacities will be along the coast with many low lying locations threatened by sea-level rise[2]. Coastal storms account for over 70 percent of recent U.S. disaster losses annually. Twenty five percent of Earth's biological productivity and an estimated 80 to 90 percent of global commercial fish catch is concentrated in coastal zones. Enhanced observations and data integration will improve our early warning and forecasting abilities, allowing our coastal communities to better prepare and respond to potential danger.

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II. GEOSS/GOOS/IOOS – HOW DO THEY RELATE?

The United States along with 70 other Countries, the European Commission and 46 International Organizations have joined together to build the Global Earth Observing System of Systems (GEOSS) over the next 10 years. The Group on Earth Observation (GEO) is an international partnership leading a worldwide effort to build GEOSS. The ultimate goal of GEOSS is to monitor the "pulse of the planet." The objective is to link all observing platforms, identify gaps in global observing capacity, and facilitate exchange of data and information for improved decision-support. The global ocean component of GEOSS is the Global Ocean Observing System (GOOS). The United States' Integrated Ocean Observing System (IOOS) is a major contribution to GOOS.

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On December 17, 2004, President Bush established by Executive Order a Cabinet-level "Committee on Ocean Policy" to coordinate the activities of executive branch departments and agencies regarding ocean-related matters to advance the environmental and economic interests of present and future generations of Americans. The COP's work is conducted through the Interagency Committee on Ocean Science and Resource Management (ICOSRMI), the Subcommittee on Integrated Management of Ocean Resources (SIMOR), and the Joint Subcommittee on Ocean Science and Technology (JSOST).

Ocean.US the United States National Office for Integrated and Sustained Ocean Observations was established by the Congressionally-created National Oceanographic Partnership Program (NOPP). The primary purpose of Ocean.US is to enhance broad user access to ocean knowledge, data, tools, and products. The goal of the interagency Ocean.US Office is to integrate existing and planned observing elements to establish an ocean observing system federation that would meet common research and operational agency needs. Since its establishment in 2000, Ocean.US has catalyzed the coordinated development of a United States IOOS. Ocean.US an interagency office supported by federal agencies. The Interagency Working Group on Ocean Observations (IWGOO) provides oversight to Ocean.US. The IWGOO membership is made up of 16 United States Federal Agencies and include: Environmental Protection Agency; U.S. Geological Survey; Minerals Management Service; U.S. Army Corps of Engineers; Office of Naval Research; Joint Chiefs of Staff; NOAA; National Science Foundation; U.S. Coast Guard; Marine Mammal Commission; USDA Cooperative State Research, Education and Extension Service; U.S. Arctic Research Commission; Food and Drug Administration; NASA; Department of State, Department of Transportation; Department of Energy

The Integrated Ocean Observing System (IOOS) is important because it will provide integrated environmental and climatological information about coastal and ocean ecosystems, which is critical for the safety of future populations and for sustaining the environment. Integrating observations and services will expand information for people, communities, states, nations, and global populations as public health, global commerce, and environmental conditions are better understood. Greater access to data and services is a significant contribution to future accomplishments. Conceptually, anyone interested in ocean observing or using ocean observations is a part of IOOS. Structurally, members include Federal agencies, state agencies, academic institutions, regional associations, trade associations, professional societies, business interests, public interest groups, and interested individuals. The IOOS model is assembling observations from diverse sponsors, thereby insuring innovation from independent perspectives and while maintaining a foundation for all the diverse components to share data.

III. NOAA'S IOOS PROGRAM

NOAA has been involved with the United States IOOS since its inception, and in order to take IOOS to the next step, VADM Conrad C. Lautenbacher, Under Secretary of Commerce for Oceans and Atmosphere and Administrator of NOAA, has established a new NOAA IOOS Program within NOAA. NOAA is committed to establishing an IOOS infrastructure. This infrastructure is critical to understanding and mitigating the effects of severe weather, global to-regional climate variability, and natural hazards. NOAA's IOOS Program will build on the vast planning and capacity that has been established so an initial operational capability for IOOS can begin.

The NOAA IOOS Program will coordinate the NOAA plan with other Federal agencies and regional partners. A large-scale enterprise such as this requires careful preparation across the entire agency for each component of the plan. In addition, the operational complexity demands a high-level management perspective within the agency. The new NOAA IOOS Program will improve IOOS because it will enable a focused communication path with participants and supporters of IOOS.

The United States' IOOS supports seven societal goals:

1) Improve predictions of climate change and weather and their effects on coastal communities and the nation;
2) Improve the safety and efficiency of marine operations;
3) Mitigate the effects of natural hazards;
4) Improve national and homeland security;
5) Reduce public health risks;
6) Protect and restore healthy coastal marine ecosystems; and
7) Enable the sustained use of marine resources.

The NOAA IOOS program, established in February 2007, has the mission to lead the integration of ocean, coastal, and Great Lakes observing capabilities, in collaboration with Federal and non-federal partners, to maximize access to data and generation of information products to inform decision making and promote social, economic, and environmental benefit to our national and the world. In establishing the office NOAA identified as its first goal to focus on the integration of data and set up an Initial Operational Capability (IOC) to be reached in thirty six months. While we understand that each of the societal goals is equally important, NOAA's IOOS Program did not have sufficient resources to address all the goals and chose to focus on the following problem set:

1. Global Climate System not well understood
2. Coastal populations at risk, including coastal hazards and coastal development and urbanization
3. Ocean, coastal, and Great Lakes ecosystems at risk, including the hydrological and biogeochemical cycles, and ecosystem health and productivity
4. Improve the safety and efficiency of maritime operations

To be able to provide measurable results in these problems we need to characterize the state of the global climate system and its variability; improve models; improve ecosystem assessments; update management approaches; and improve access to data, and scientific information. To do this, the NOAA IOOS Program will concentrate on delivering integrated data to four theme areas through what we are calling the Data Integration Framework (DIF). The NOAA IOOS Program will initially concentrate on delivering five of the twenty core variables taken from the United States' IOOS Development Plan that represent a collective effort across interagency partners to determine the top twenty variables that are most important to integrate. The five variables are: Temperature, Salinity, Sea Level, Surface Currents, and Ocean Color. The four theme areas are Hurricane Intensity Model, Coastal Inundation Model, Harmful Algal Bloom Model, and Integrated Ecosystem Assessment. The NOAA IOOS Program has set a 12-month goal to create the DIF necessary to integrate these five core IOOS variables for routine access and use. The 18-month goal is to place these integrated variables into four specific theme areas—Hurricane Intensity Model, Coastal Inundation Model, Harmful Algal Bloom Model, and Integrated Ecosystem Assessment. The 24-month goal is to test and evaluate these products, and by 36 months, the benchmarked products will be improved for operational use.

IV. DATA INTEGRATION FRAMEWORK

Why do we need a Data Integration Framework (DIF)? NOAA collects data from multiple platforms for specific purposes. Once those purposes are satisfied, data are archived. The full suite of data is not organized to respond to NOAA's priority needs for real-time decision-making. Integration of the data being collected by existing assets is necessary to adequately improve decision-making and assess NOAA wide observation gaps. We looked at the collection of sea surface temperature across NOAA. Over thirteen platforms collects SST, data are transmitted through various communication paths to a number of data distribution points across NOAA. Data are archived in different locations at different spatial and temporal scales. There is not a single, integrated temperature database in NOAA or anywhere else. Models to support our four theme areas are not fully utilizing the data that NOAA is collecting yet there are requirements for additional observation platforms. Finally, we need to address that integration is meaningful. The NOAA DIF is a risk-reduction effort to better define the technical requirements and risks on a small scale and at a low cost before proceeding further on a larger scale and higher costs. There are two hypotheses being tested in establishing this framework (1) That NOAA has the ability to integrate data with the current organizational structure, regulations, and decision processes and (2) that there is value to this integration that can be measured.

Since work on this project began in February, we have made considerable progress towards determining our baseline situation and identifying what is required to build the DIF. We have approached this from three angles, the data flow; how easy is it to access the data, and standards. To better understand the data flow, we met several times with developers of the models to support our four focus areas. The results from these meetings were customer needs reports from which we were able to distill information relating to their current usage of data, as well as what their needs for additional data. We graphically traced the data flows from platform to data model, and are beginning to document the true temporal and geographical resolutions of the data needs. This allows us to get a better handle on what the "as is" condition is and to begin to develop a plan for where we need to go.

For the focus area of Integrated Ecosystem Assessment (IEA) we teamed with an existing NOAA program called Pacific Coast Ocean Observing System (PACOOS) to begin the development of the ecological component to IOOS for ecosystem based management. An IEA is defined as a synthesis and quantitative analysis of information on relevant physical, chemical, ecological and human processes *in relation to specified ecosystem management objectives*". An IEA will incorporate multiple indicators of the environment and ecosystem, including human factors, is geographically specified, establishes target levels and thresholds for important ecosystem components and evaluates the impacts of management options and risks of not attaining target ecosystem states. IEAs provide a "big picture" understanding of an ecosystem by interpreting complex interactions among physical, biological, chemical and human processes. Provide a fuller examination of economic trade-offs, and enable decision makers to explore optimal management scenarios that may not be evident with single species assessments. While providing the integration of the first five variables will not complete an IEA, it does represent a focused effort by NOAA and partners to integrate traditional physical oceanographic data with biological and ecological data. As well, we have started to better understand and characterize the biological data in a way that it can be shared.

The next step we need to accomplish was to understand whether we could actually pass data across NOAA programs. To do this we conducted what we called 5 "interoperability" tests, one for each of the 5 initial core variables, to assess NOAA's present level of data compatibility between distributed data sources, as well as what the current ease of data access. We did this through three NOAA organizations – the Coastal Services Center, the National Data Buoy Center, and the National Coastal Data Development Center. Each of these centers set up a test to look across NOAA's major data servers to retrieve data for a specific location and time period to see whether without manipulation these data were interoperable. In all cased we found that it was not possible to pull the data from desperate sources and immediately use the data. The results indicated that:

- Incompatible data formats and content prohibited integration of multiple data sources without programming support and/or advanced end-user client tools (e.g. Matlab, Arc GIS).
- Data structures (e.g. row/ column structure) across all services were generally inconsistent.
- Very few sources of data exist where access is through a user-friendly, queriable services based interface.

- Each data source uses different forms of temporal and spatial expressions and vocabularies; many different data dictionaries.
- Spherical coordinates, latitude and longitude, were generally used, however in varying formats.
- Metatdata were either unavailable all together or if they did exist were not located with the data, and difficult to find.

An added challenge was IT security. NOAA and others make use of open community software such as OPeNDAP. In April, some of NOAA's OPeNDAP servers were hacked resulting in NOAA taking its OPeNDAP servers offline. We had to have special permission from the NOAA CIO structure to have specific servers made available for follow-on testing. But what this really means is that NOAA and the larger IOOS community need to address the broader security issues related to open source software in general.

So we talk about standards and there is little understanding of why this is so hard. One reason for this is in the way we have traditionally funded programs. Data management does not sell, end users products do, so the data management cost is buried inside many projects. The result is that each project spends resources to format the data to their particular needs. In the end we have many incomplete standards but few community wide standards. From a more technical view it is not just one standard when you talk about a variable. There are type and functional categories for each standard. If you trace this out to the full extent you come up with a 56 block matrix for each variable. Examples of types of data type include: grids, scattered points, trajectories, time series, moving-sensor multidimensional fields and collections, profiles and geospatial mapping data (coastlines). Functional categories include: data transport and access, metadata, QA/QC and IT Security. Within each of these functional categories, you will have standards and protocols (and possible multiple ones) for each of the types of data that ocean observations come in. For example, transport of time series data may be better handled by a different protocol than that for transport of grid data.

The NOAA IOOS Program is in the process of gathering the various standards associated with our five core variables across the United States IOOS community to determine how many can be adopted, how many adapted and how many we need to write. It is our plan to then provide the resources to put these standards through the United States IOOS – Data Management and Communications (DMAC) process so we can gain community wide standards.

V. Regional Capacity

The United States IOOS is National, Regional and local in nature. I have already talked about the National which is the Federal Agencies. The Regional and local partnership of IOOS is critical as it extends the understanding, monitoring and delivering of operational products to a wide variety of users. Within the United States there are 11 regional associations that oversee a number of regional coastal ocean observing systems (RCOOS). These RCOOS represent platforms, modeling, and data products both in research mode and operational mode. The Regional Associations are partnerships between the Federal government, State Governments, Academia and Industry and allows each region to understand the local needs for the United States IOOS system.

One example where the partnership works very well is based on a specific data platform know as High Frequency Radar (HF radar). A combination of Federal sourced money has been distributed with the regional construct and we are well on our way to demonstrating the capabilities of a National HF radar plan. While the United States has deployed 85 radars, many of them are tied to specific projects that are only in existence for the duration of that project. We need to work on the sustainment of the capacity and other like capacities as the United States builds a regional coastal ocean observing system.

VI. Industry partnershps

Industry is another partner in this endeavor. Industry can contribute to every aspect of developing, operating and using the U.S. IOOS, but there are resource constraints. We are still in the period of discovery concerning the many technical challenges associated with developing the U.S. IOOS. From providing infrastructure, systems integration, observation platforms and commercial applications industry is key to the success of a United States IOOS. The United States funded two industry studies in 2006 and Raytheon and Lockheed provided valuable concept designs that validating the technical feasibility of building an IOOS & in providing conceptual notions of what an IOOS could and should look like.

Another example is the NOAA Chesapeake Bay Interpretive Buoy System (talking buoy) is designed to mark significant points along the Captain John Smith Chesapeake National Historic Trail and to provide current information about weather, oceanographic, and water quality at different points along the trail. CBIS is the water counterpart to the United States Appalachian Trail – a first of its kind. Great partnership between the NOAA, Conservation Foundation; Chesapeake Bay Foundation, Sultana Projects; America's 400th anniversary Official Statewide Partner; National Park Service; National Geographic; Friends of the Captain John Smith water trail; and Verizon wireless. As well there was a strong partnership with industry – the buoy was purchased from Bought the buoy from Axys Technologies INC; NOAA worked with WET Labs INC to develop a new water quality instrument, a Nortek AS ADCP was mounted on the buoy, Tellus Applied Sciences provided the data management and web design, Verizon wirelsess the data transmission and Verizon Business system provides the data to voice conversion – business application adapted for buoy use.

Commercial applications companies such as Surfline, and Roffer's Ocean Fishing Forecasting Service, Inc (ROFFS™) provide support specific communities. Surfline is a leading provider of surf report and forecast information to consumers, businesses and government agencies worldwide. ROFFS™ is a scientific consulting company that is involved with fisheries oceanography, environmental science, and satellite remote sensing. ROFFS™ provides tactical and strategic fisheries forecasts, ship routing, oil and gas drilling operations, seismic and fish surveys, fisheries development, aquaculture, environmental monitoring, and applied scientific research.

VII. CONCLUSTION

In conclusion, NOAA is the first Federal agency to stand up an IOOS program office. We are striving to ensure that we are supporting the United States IOOS and will have the ability to set the path for a larger more comprehensive United States IOOS program that moves from the development phase to the execution phase. There are challenges we need to work through. On the technical aspect, it is not easy to integrate data from disparate sources and provide them in formats and at rates that are useful for a broad array of applications. From a Program perspective, IOOS is not "owned" by one agency or entity. It is difficult to engineer a cohesive and fully operational system when there are numerous stakeholders that contribute to and also use this system. Finally, from a budgetary perspective there are fiscal constraints that are always an issue in any program; IOOS is no exception. Coordinating federal budget requests across agencies is not typical or easy

At the National level, the U.S. IOOS is a coordinated network of people, organizations, and technology that generate and disseminate continuous data about our coastal waters, Great Lakes, and oceans. The power of IOOS is synergy. By working together to integrate data to provide a broad, detailed, and synoptic view of our coastal, Great Lakes, and ocean environments, IOOS increases knowledge and enables better and smarter coastal and ocean-related management decisions. This coordinated data network will allow the scientist, farmer, teacher, emergency responder, environmental resource manager, and many others rapid access to comprehensive information on demand and in formats that are useful for making everyday decisions and improving our overall quality of life. By creating the NOAA IOOS Program, NOAA will work with our Federal and non-Federal partners to ensure that all of this critical data is organized and accessible to the United States and the world.

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